# Geological Sciences

## Rheology

Dynamic processes within the Earth are limited by the strength of the minerals at elevated pressure and temperature. Deviatoric stresses cause earthquakes and mantle flow. Deviatoric stresses in the high pressure systems can now be monitored and quantified. Their time dependence reveals the relaxation mechanism. Pressure and temperature dependencies can relate to depth variations in the Earth. Current x-ray resolution of deviatoric stress is about a kilobar, far more than exists in most of the Earth's mantle, but comparable to seismic regions. Thus, even now we can approach geologically relevant *P*, *T*, and stress conditions. Within this framework, rheological studies for several materials are reported in this volume. Earthquakes persist into the Earth's transition zone. The time dependence of strength for the relevant minerals of this region are reported by J.-I. Ando *et al.*, Y. Wu *et al.*, and J. Chen *et al.* (SUNY @ Stony Brook) Included in these studies are the silica rich garnet, majorite, and the high pressure phase of olivine, wadsleyite. Indeed, the role of water weakening is also reported. Olivine is a classic material in which a small (ppm) amount of water drastically reduces the strength. The high pressure forms of olivine (wadsleyite and ringwoodite) can structurally bound a considerable amount of water (up to 3 wt %). The results of J. Chen *et al.* and T. Inoue *et al.* (SUNY @ Stony Brook) suggest that these high pressure phases are not appreciably weakened by the presence of large amounts of water, even though olivine, at these high pressures, is still strongly affected by trace amounts of water. These studies have significant implications concerning the seismic potential of different chemistries within the upper mantle and transition zone. All of these studies were carried out on X17B1.

## Equation of State

High temperature equations of state are important in extrapolating phase boundaries to higher pressures and temperatures than where they are defined. Significant work in this area has also been carried out on X17B1. This motivated K. Bose *et al.* (Princeton U.), to obtain the equation of state of antigorite, a hydrous rich low pressure phase. The stability field of hydrous minerals help define the mass balance of hydrogen into the Earth's deep interior.

Equations of state of stishovite (J. Liu *et al.,* SUNY @ Stony Brook) and Ca(Ti/Si) perovskite (Y. Sinelnikov, *et al.* SUNY @ Stony Brook), provide important information concerning the temperature dependence of the bulk modulus and are relevant to matching the depth behavior in the Earth of the bulk modulus. The equation of state and phase equilibria of Fe-Si alloys studied by J. Zhang (SUNY @ Stony Brook) and F. Guyot (U. of Paris) address possible alloying in the Earth's core.

## Phase Equilibria

T. Shen *et al.* (Los Alamos National Laboratory), with the double hot plate high pressure high temperature system continue the exploration of the iron phase diagram. In the study reported here, they find no evidence of the illusive phase transition in the epsilon phase as previously reported by suggesting that this phase may be created on quench. Surely, this debate has not ended.

With the expansion of the experimental environmental envelope has come a remarkable expansion in types of studies that can be done in conjunction with x-ray synchrotron radiation. The most significant breakthrough for Earth related studies is the inclusion of acoustic velocity measurements at high pressure and temperature and simultaneously with x-ray diffraction. This development is discussed in the instrumentation section and has already been used on X17B1 to collect acoustic data on polycrystalline specimens of majorite, a silica rich garnet (G. Gwanmesia *et al.,* Del. State U.) and the high pressure form of olivine, wadsleyite (B. Li *et al.*, SUNY @ Stony Brook). These two phases are stable at the high pressures and temperatures of the Earth's transition zone and are expected to constitute the bulk of this region of the Earth's interior. With these new data, we will be able to examine various chemical models of this region of the Earth.

P. Conrad *et al.* (Carnegie Inst. of Washington), use the focusing capability of the X17 system to explore a natural high pressure device, that is a natural diamond with inclusions as specimens. Presumably, the inclusions were emplaced while the entire system was at high pressure. Residual stresses will still exist within the inclusion owing to the extremely large bulk modulus of diamond. Removal of the inclusion risks back transformation of the minerals to low pressure phases. Thus, the structural determination with synchrotron x-rays provides a nondestructive probe.

## Microprobe and Microspectroscopy

There were a number of experiments carried out on geological samples at X26C, including those by I. Steele (U. of Chicago) on Au in sulfides, and Ni, Zn, Ga, Y and Zr in garnet. J. Rakovan and R. Reeder (SUNY @ Stony Brook) studied the spatial resolution of trace elements such as Y, Sr, Mn, La, Ce and Pr in apatite samples the interest being in the relationship between the details of the structure of the host material and the amount and distribution of the impurity. Other types of impurity, namely fluid inclusions were studied by R. Mayanovic (Southwest Missouri State U.), A. Anderson (St. Francis Xavier U., Canada) and S. Bajt (LLNL). Here ppm concentrations of Zn, Pb and Fe were found in individual inclusions and in particular ZnCl dominated and was studied at elevated temperatures where its persistence was attributed to a high concentration of chloride in the inclusions. Trace elements were also studied in samples of interplanetary dust particles (G. Flynn, SUNY @ Plattsburgh), S. Sutton (U. of Chicago) and S. Bajt (Lawrence Livermore National Laboratory) of two main types and compared to the distribution in meteorites.

G. Cody (Carnegie Institute of Washington), H. Ade (North Carolina State U.), and S. Wirick (SUNY @ Stony Brook) at X1A used carbon XANES analysis to examine organic rich sedimentary rocks. The $1s$-$\pi^*$ transition of carbon revealed specific chemical signatures for particular layers and phases.